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[54] **AIR BAG FOR USE IN A MOTOR VEHICLE AND METHOD OF PRODUCING SAME**

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[21] Appl. No.: **385,904**

[22] Filed: **Feb. 9, 1995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 259,869, Jun. 15, 1994, abandoned.

[51] **Int. Cl.**^{6} **D04H 3/02**; D03D 1/02

[52] **U.S. Cl.** **28/104**; 28/106

[58] **Field of Search** 28/104, 103, 105, 28/106, 107, 109, 110, 111, 112, 115, 163, 165, 167; 248/68.1, 300, 362, 363; 209/397; 33/563, 565; 428/131, 134, 135, 136

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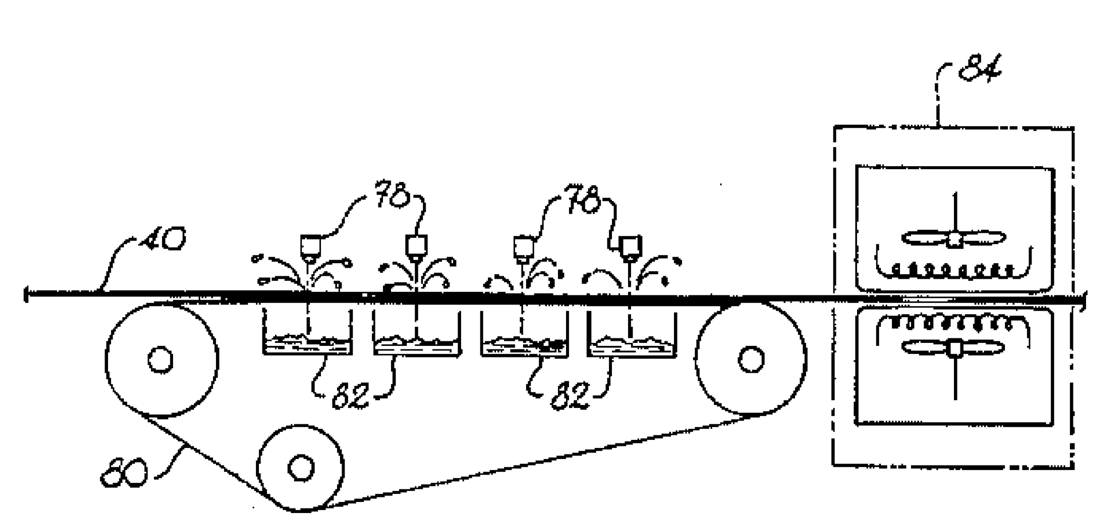
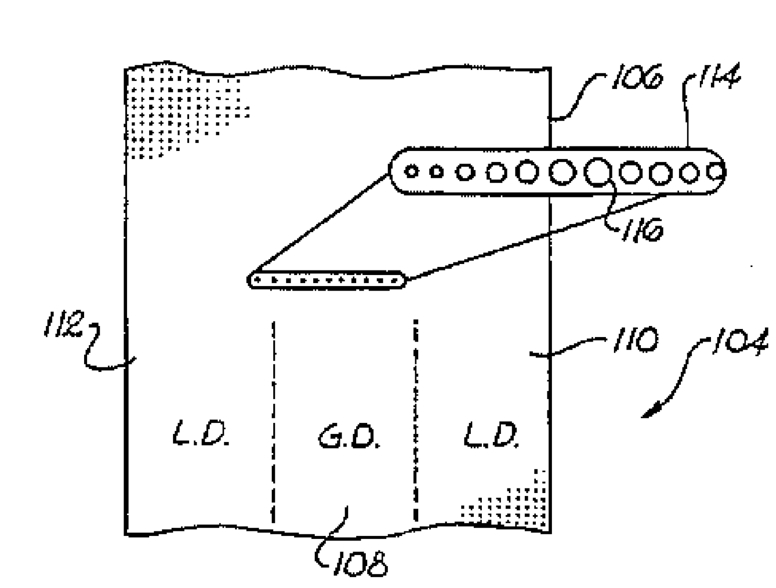
Attorney, Agent, or Firm—Dority & Manning

[57] **ABSTRACT**

An air bag of the type utilized in a vehicle occupant restraint system is constructed of a plurality of panels of uncoated fabric. Respective of the panels have been processed to achieve a selected air permeability with greater accuracy on a lot-to-lot basis than had generally been achieved with uncoated fabrics of the prior art. In one presently preferred methodology, a plurality of fluid jets, preferably water jets, are utilized to impact panels of the uncoated fabric under selected operating conditions. Pores created by the fluid jets may be heat set to achieve a selected permeability. Fluid jet processing may also be utilized to produce a fabric having a selected thread count.

11 Claims, 8 Drawing Sheets





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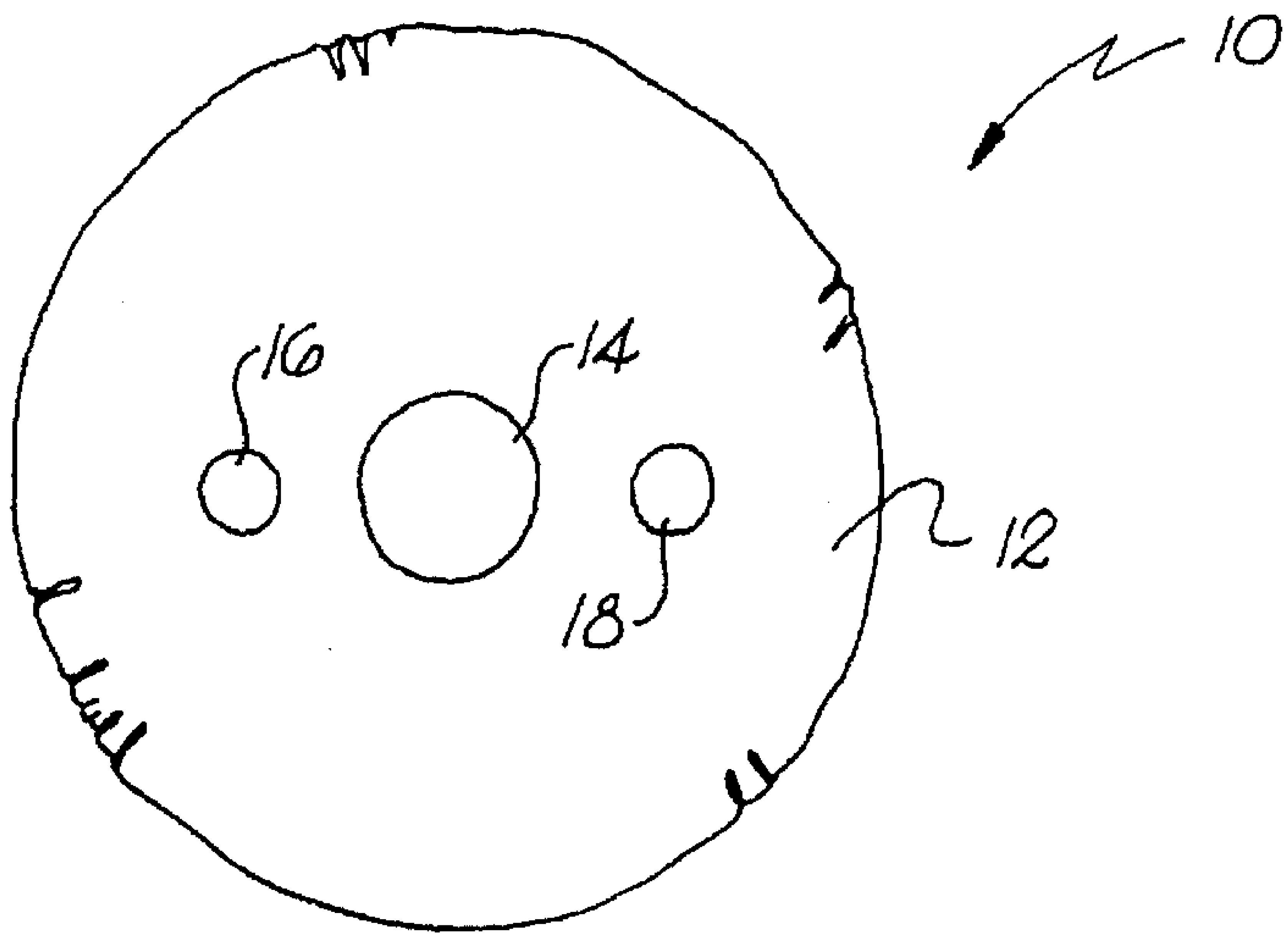


PRIOR ART

Fig. 1

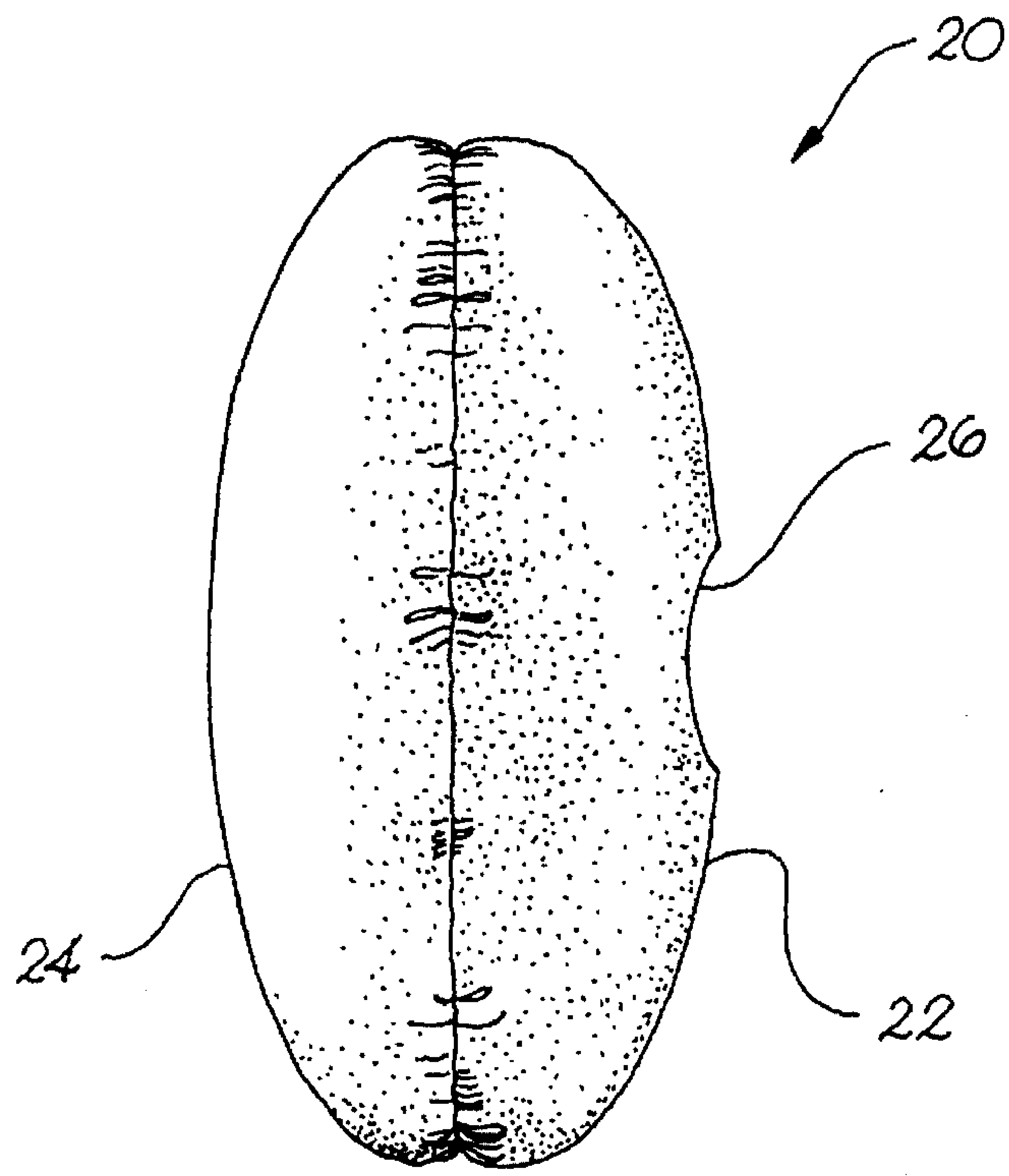


Fig. 2

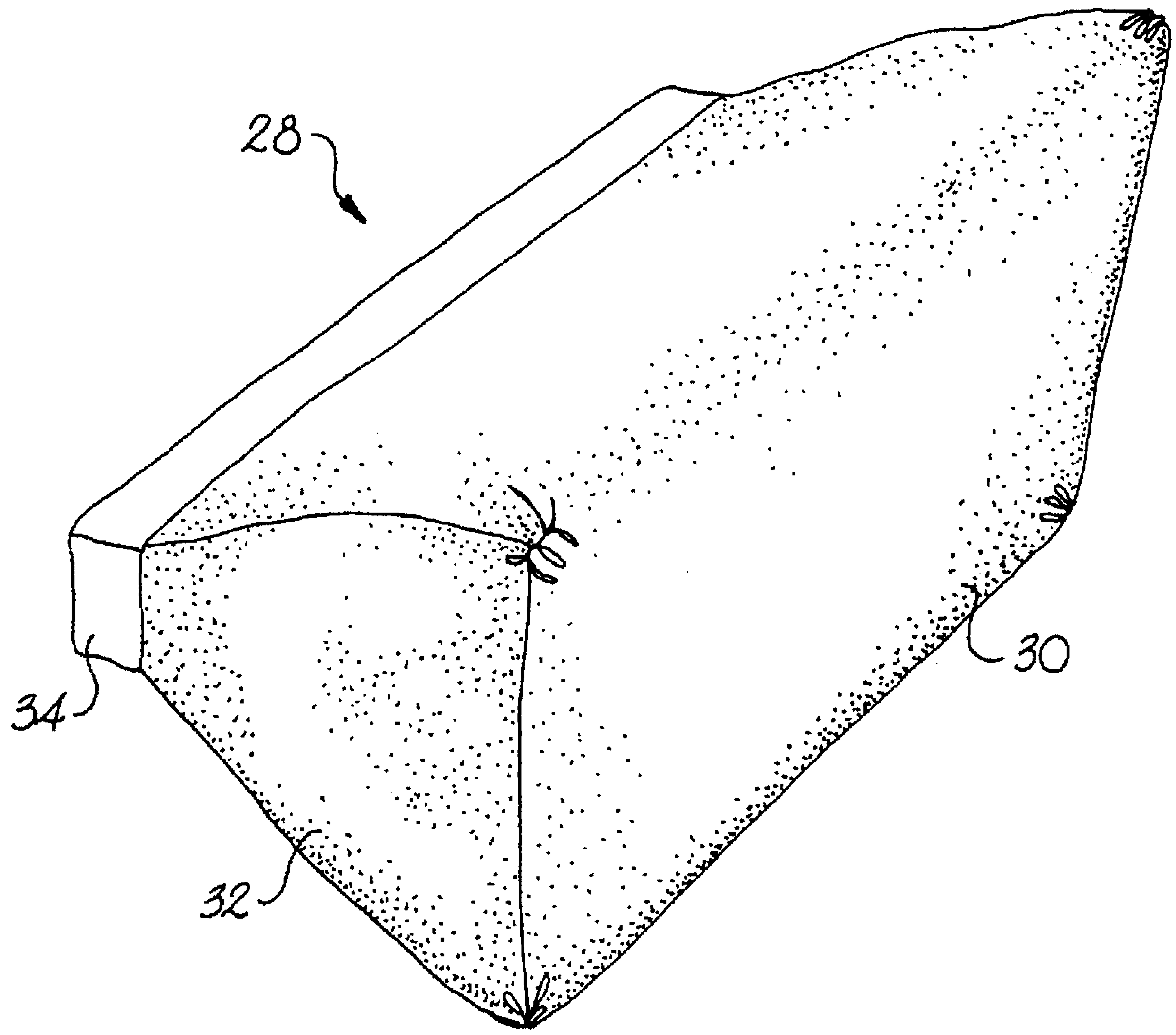


Fig. 3

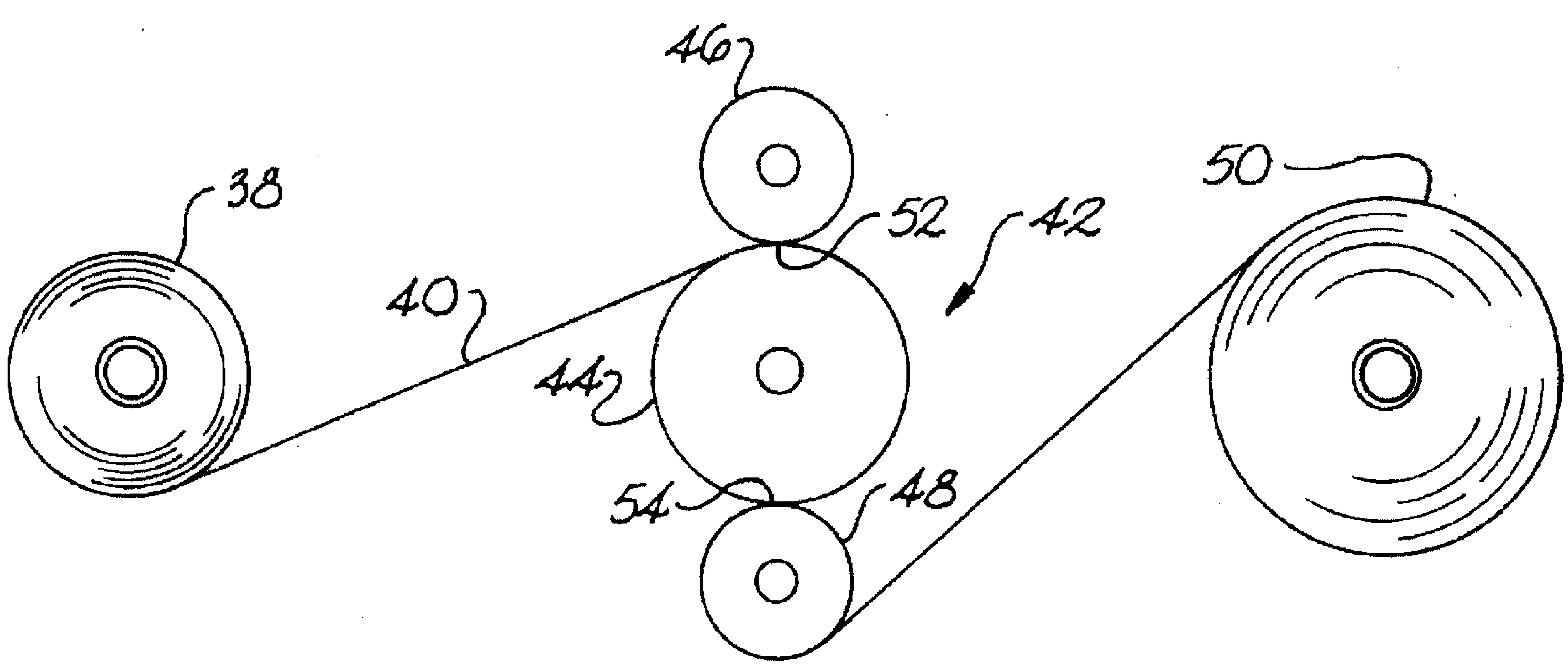


Fig. 4

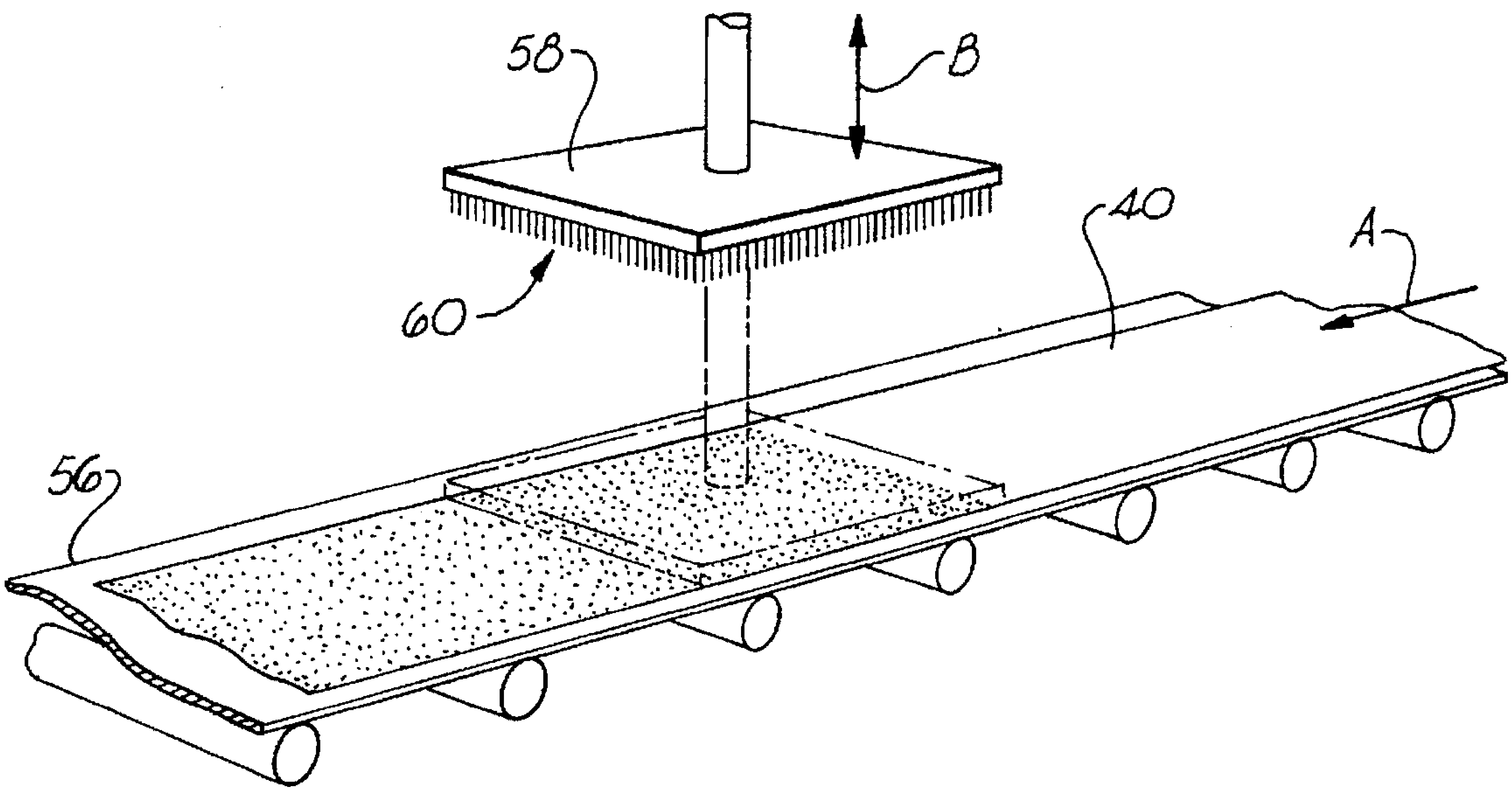


Fig. 5

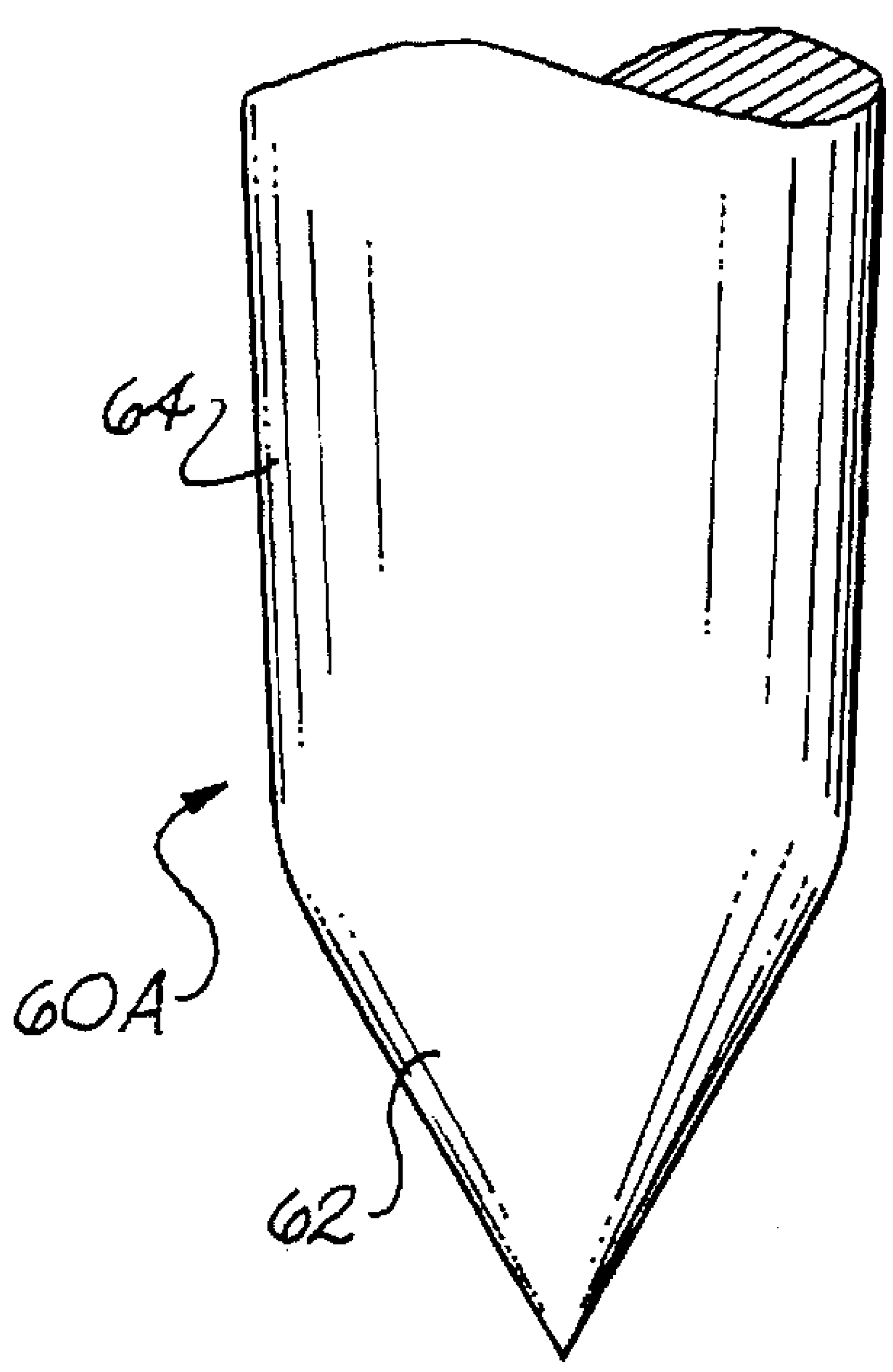


Fig. 6A

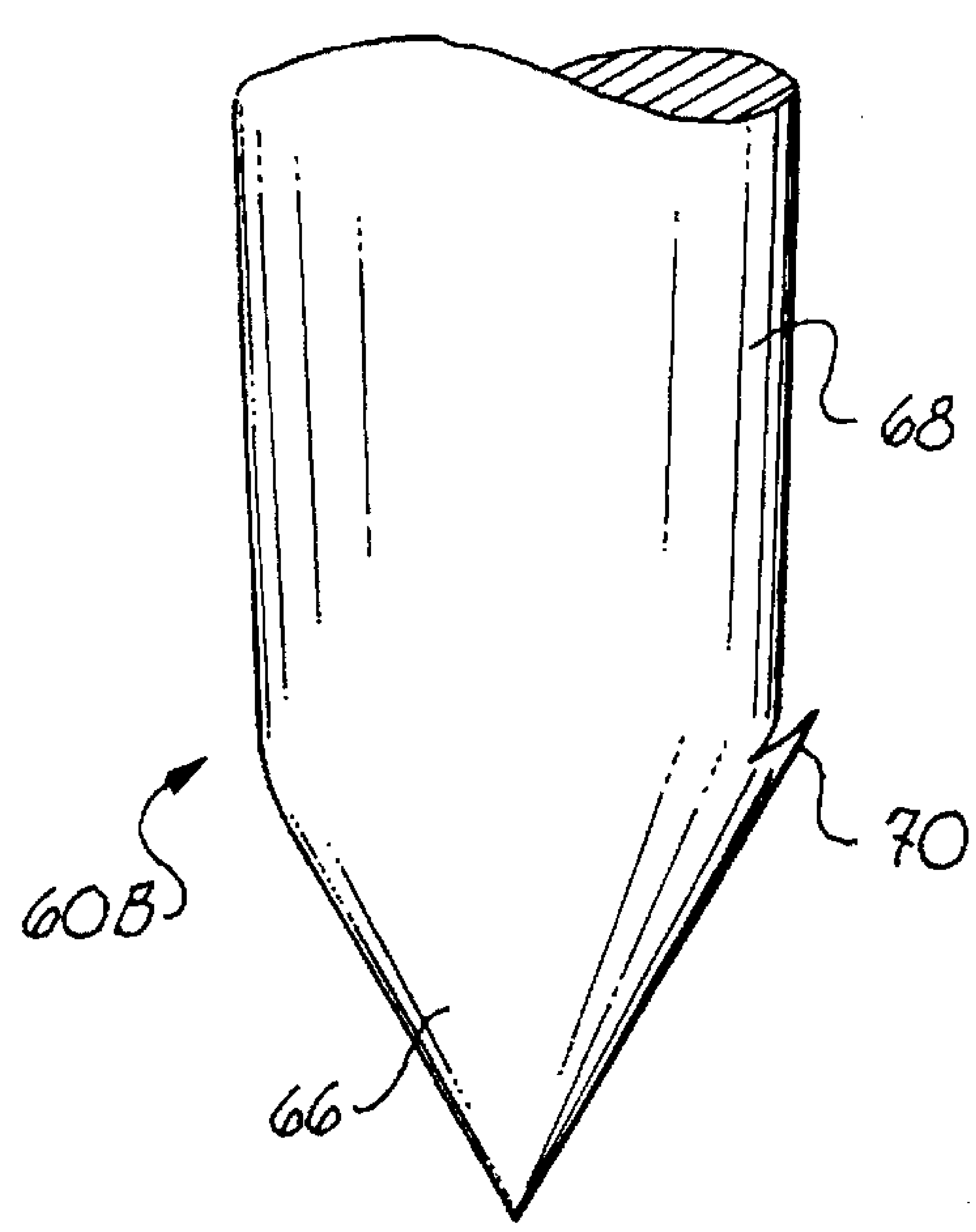


Fig. 6B

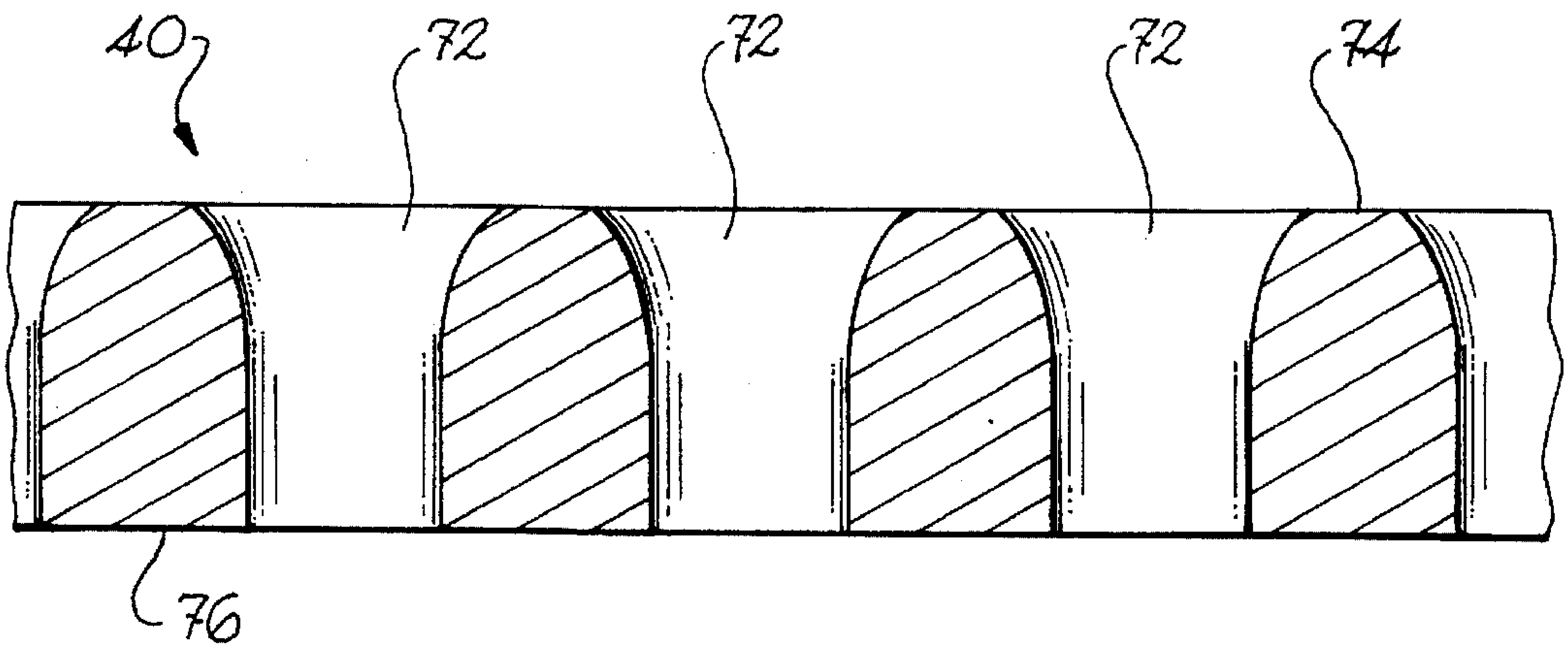


Fig. 7

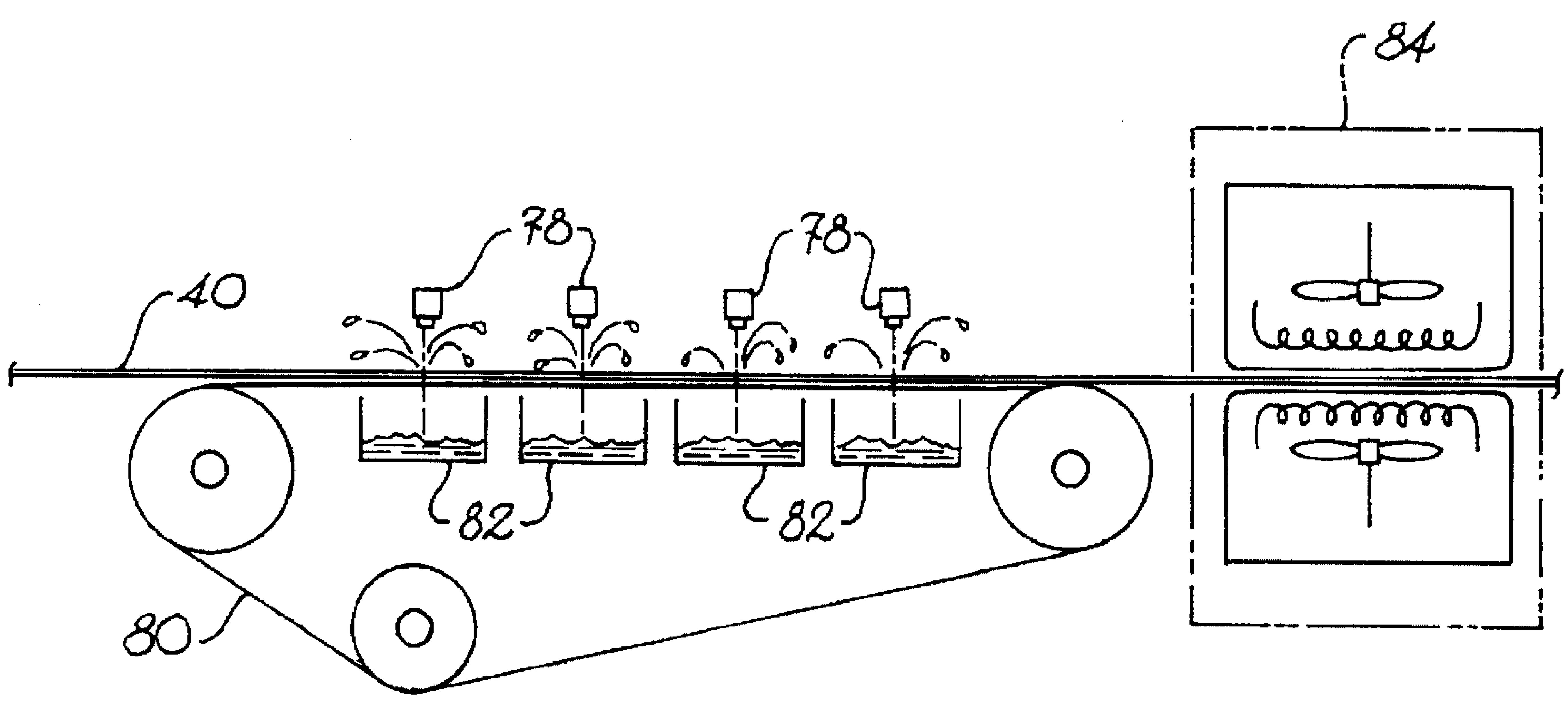


Fig. 8

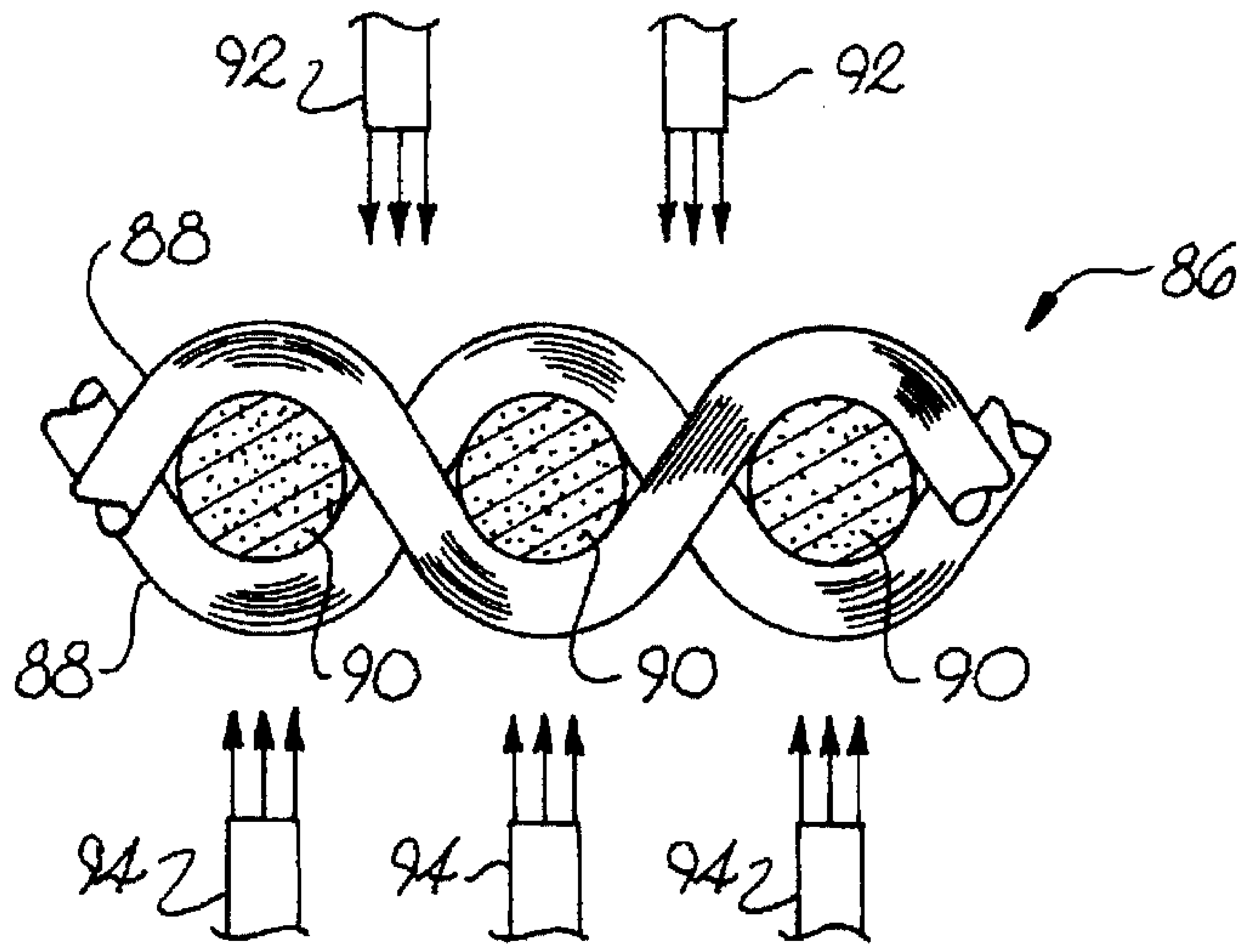


Fig. 9

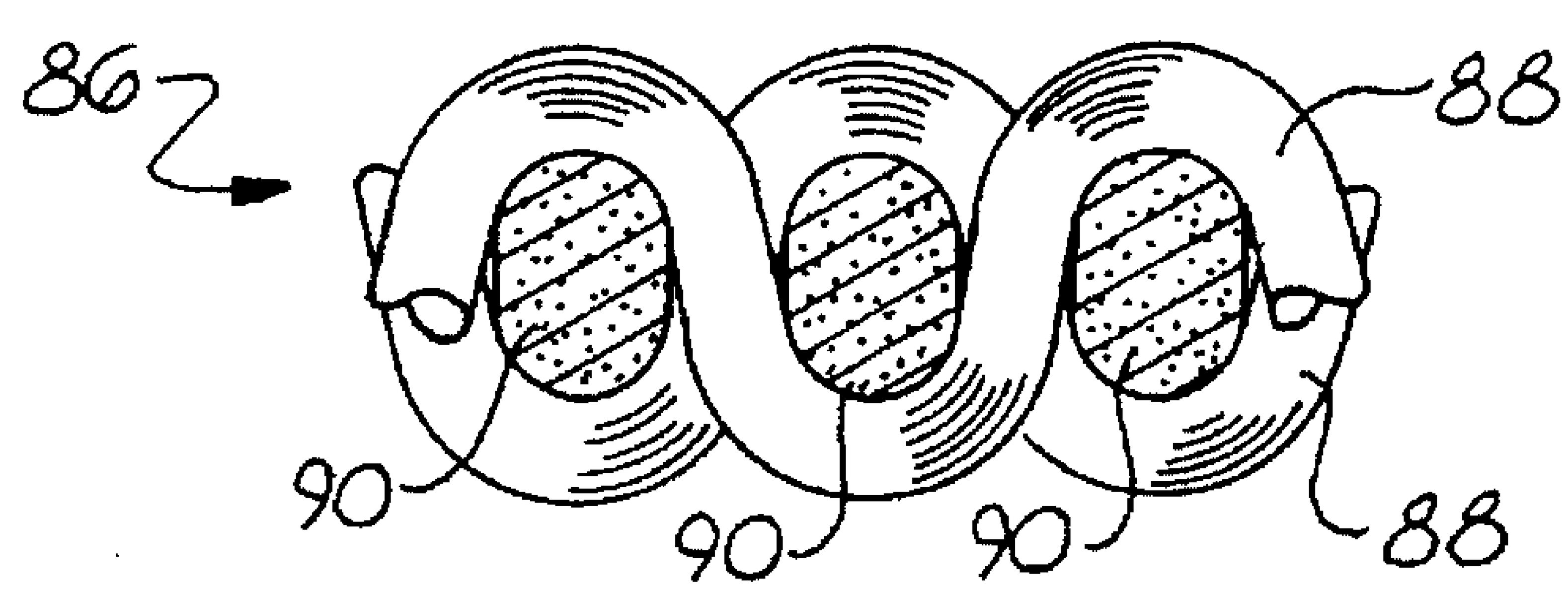


Fig. 10

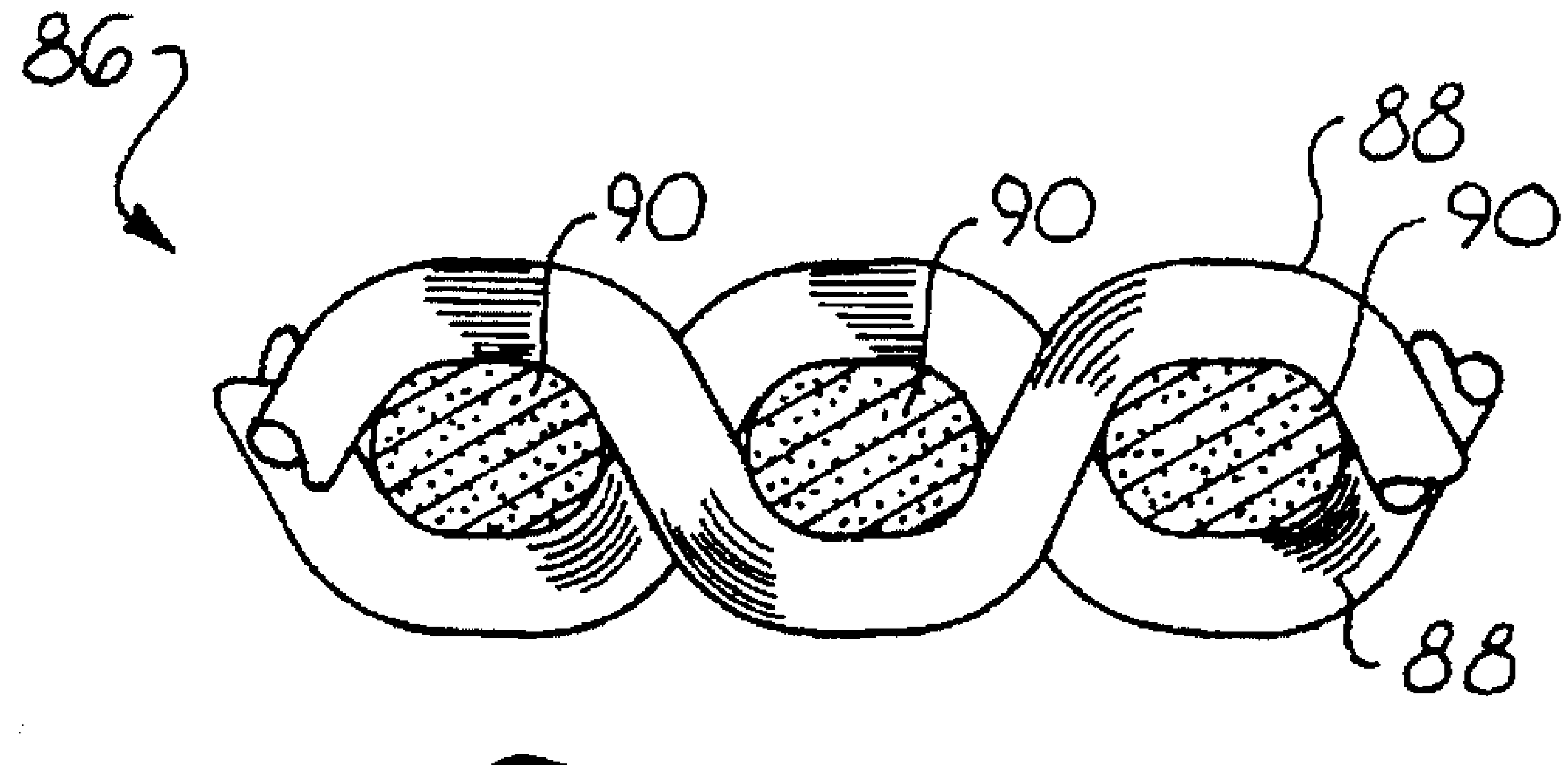
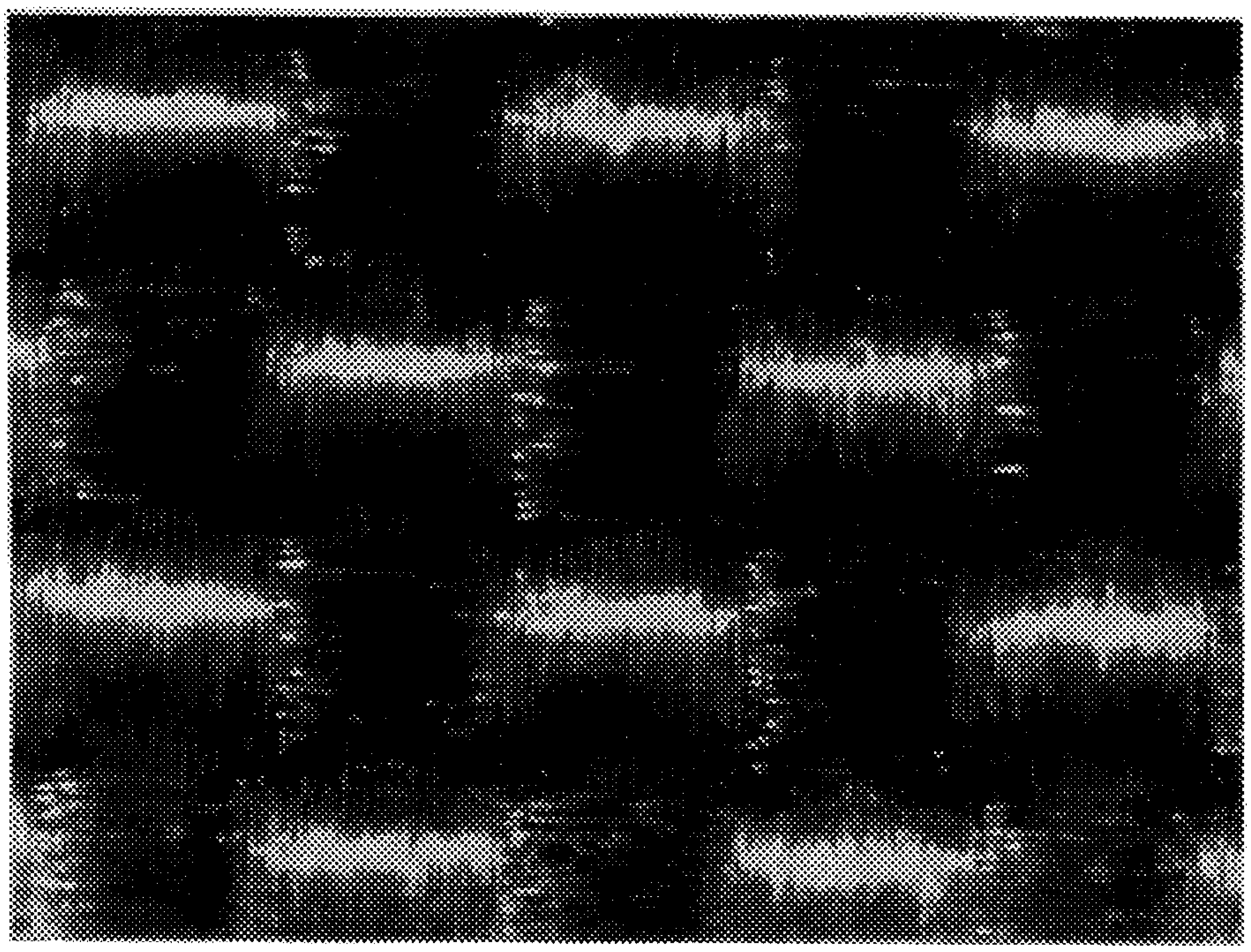
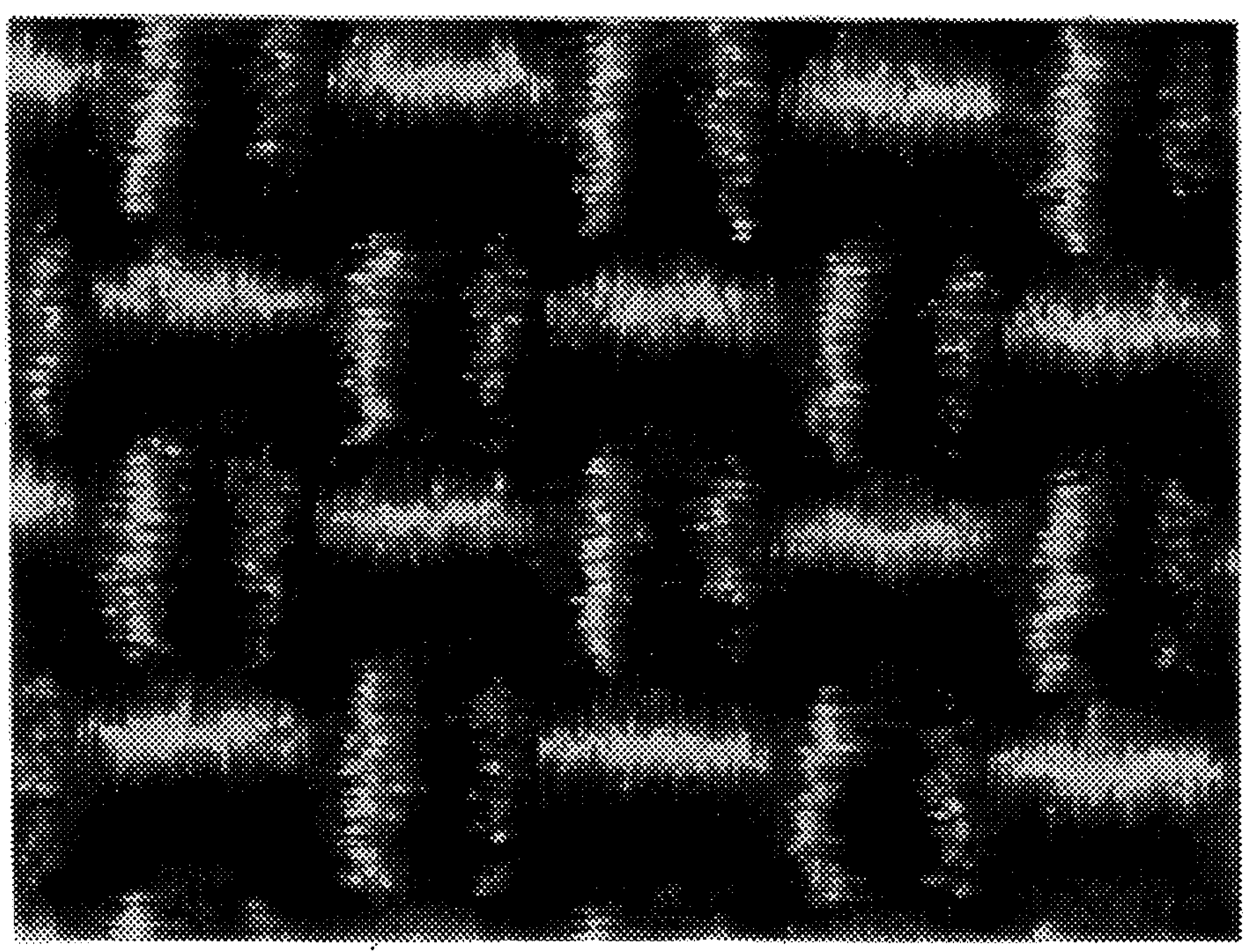


Fig. 13



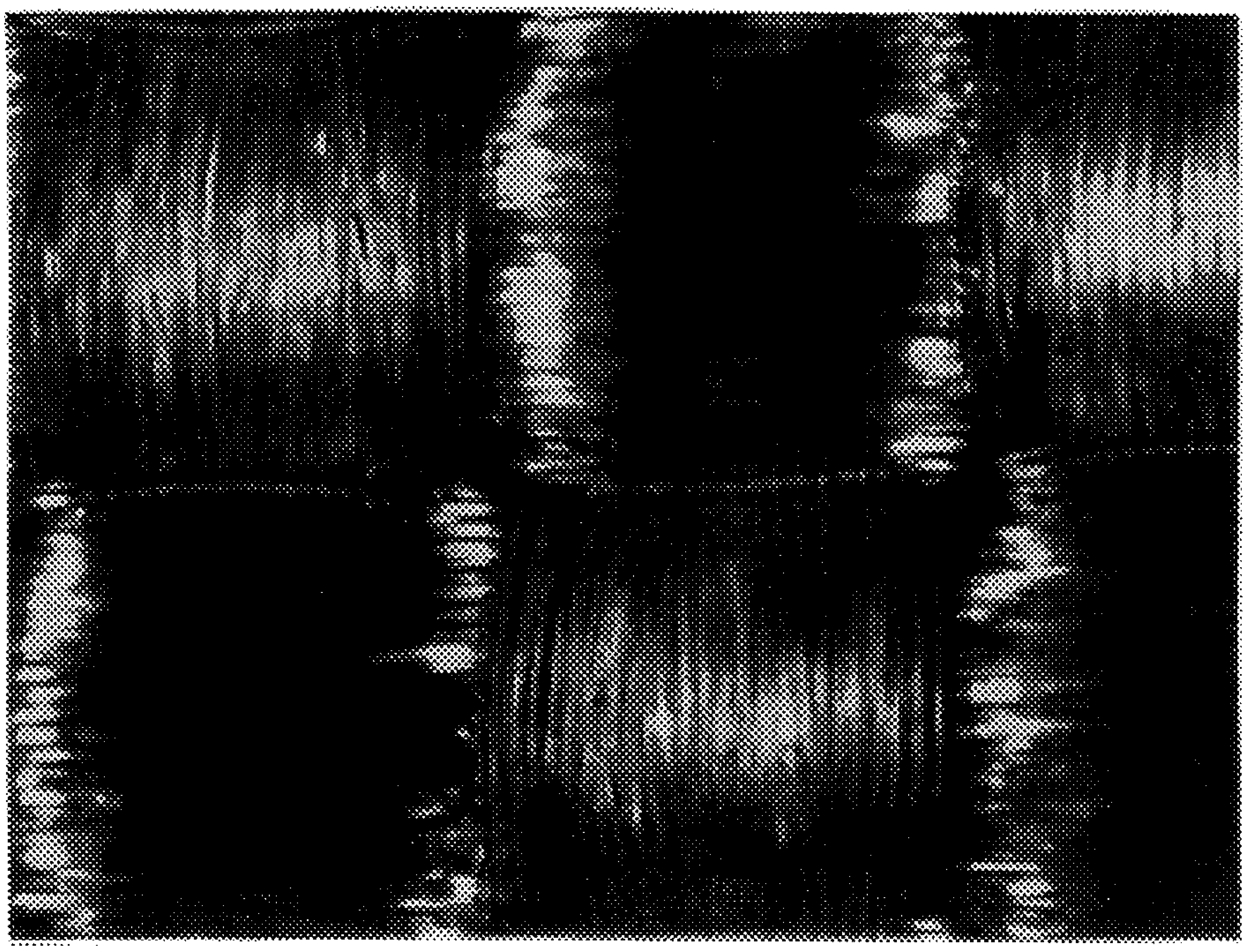
CONTROL

Fig. 11A



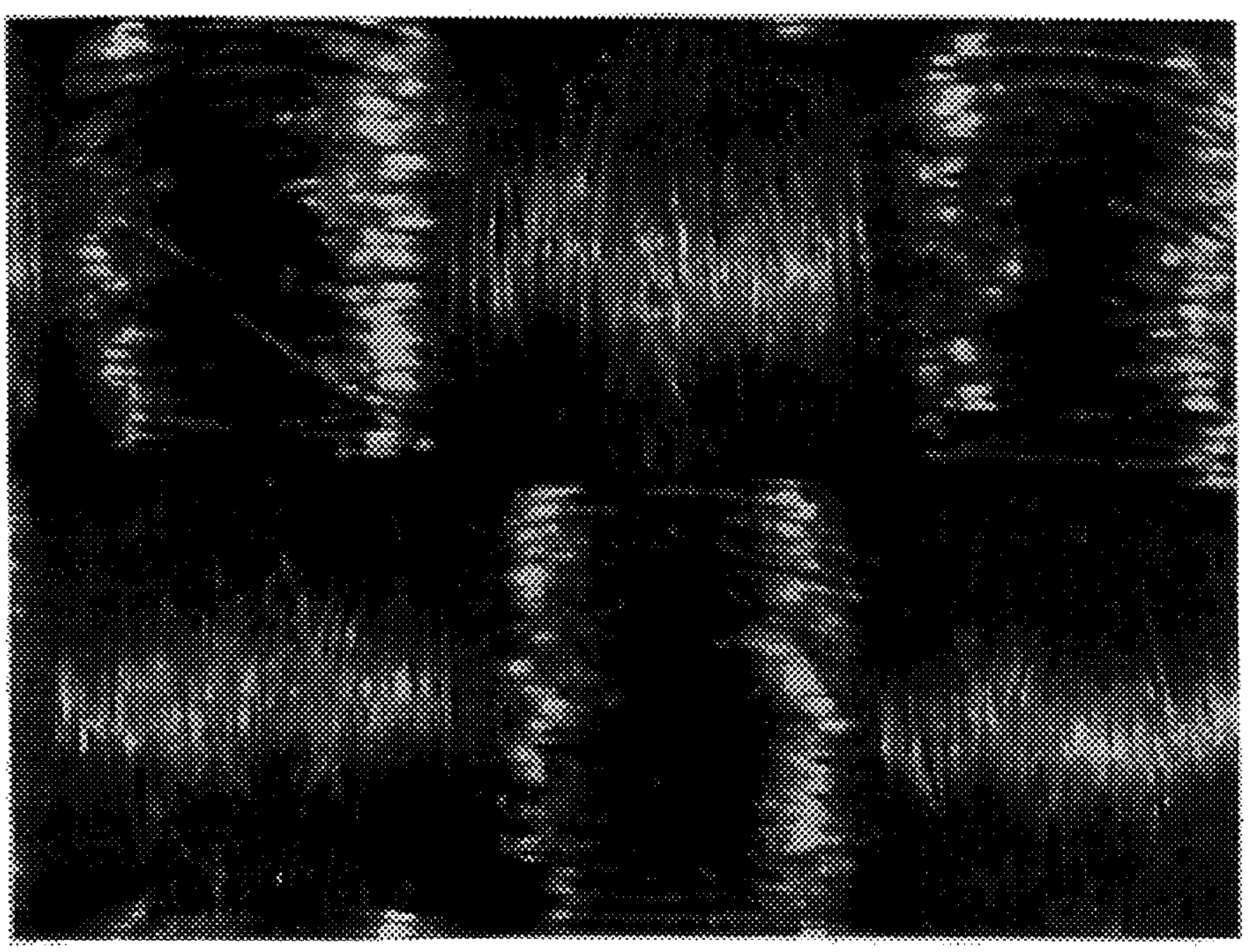
ENHANCED

Fig. 11B



CONTROL

Fig. 12A



ENHANCED

Fig. 12B

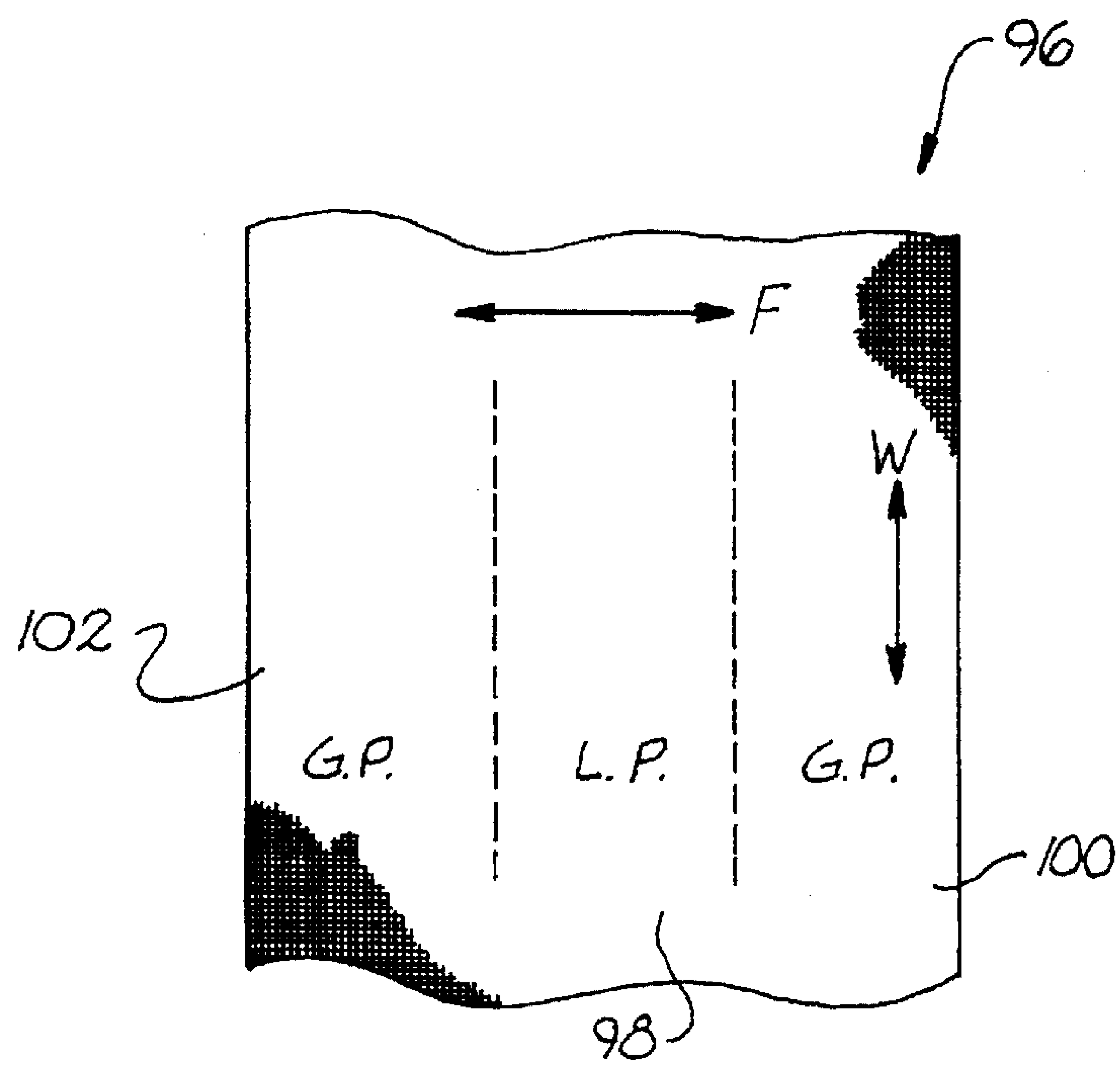


Fig. 14

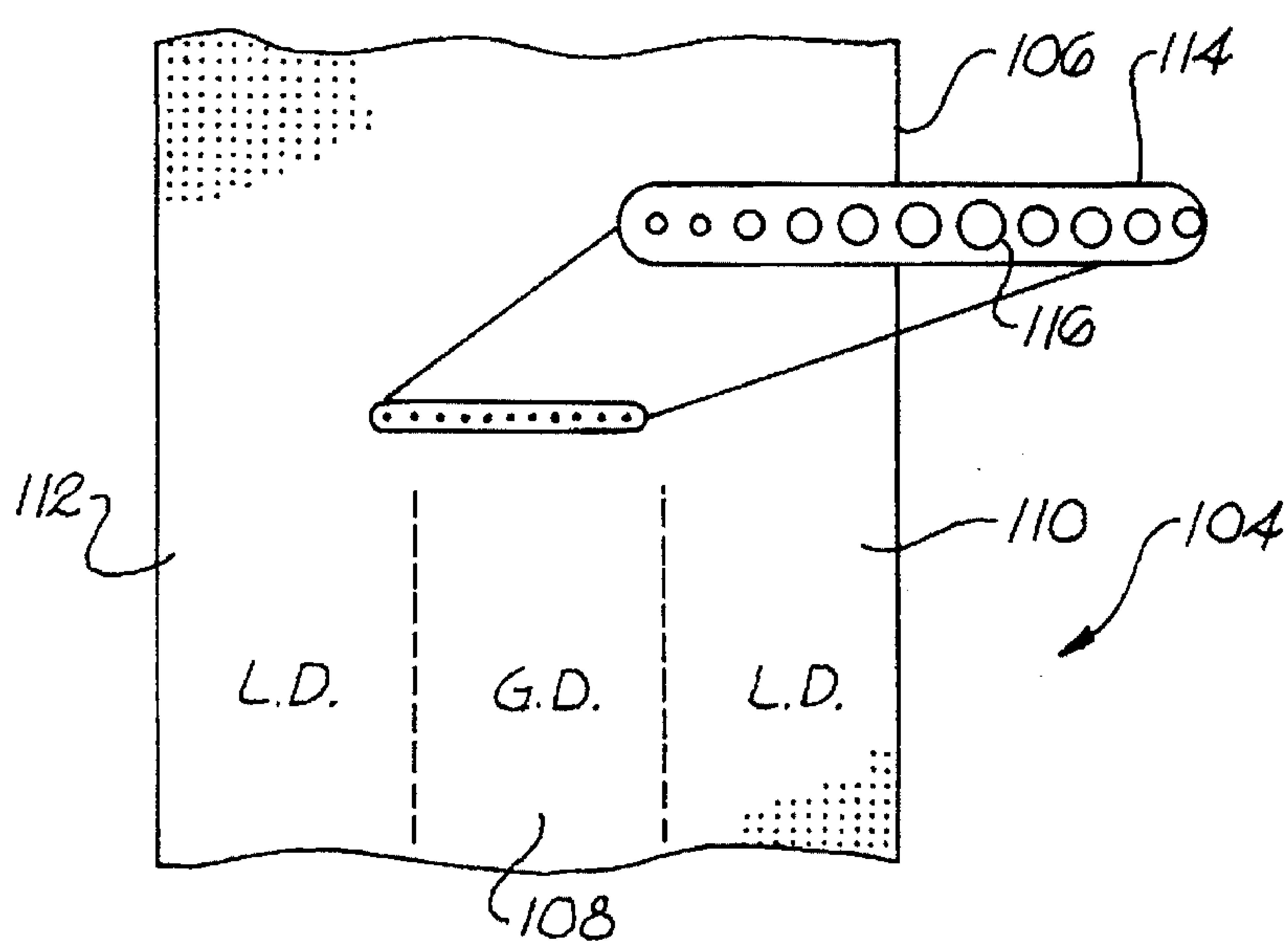


Fig. 15

AIR BAG FOR USE IN A MOTOR VEHICLE AND METHOD OF PRODUCING SAME

CROSS-REFERENCE TO A RELATED APPLICATION

This application is a continuation-in-part of U.S. Ser. No. 08/259,869, filed Jun. 15, 1994, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates generally to air bags of the type utilized in vehicle occupant restraint systems. More particularly, the present invention relates to a vehicle air bag constructed substantially entirely of an uncoated fabric, as well as methods of producing such an air bag.

Virtually all motor vehicles in service today are equipped with seatbelts to restrain vehicle occupants during a collision. Recently, however, many vehicles have also been equipped with air bag systems to supplement the protection provided by seatbelts. These air bag systems utilize at least one folded air bag in fluid communication with a source of inflation gas. A sensor is provided to detect a collision between the vehicle and another object. When such a collision is detected, the sensor actuates the source of inflation gas. As a result, the air bag is rapidly expanded to absorb at least a portion of the impact force which would otherwise have been imparted to the vehicle occupant.

Typically, the air bag is designed to inflate in a period which generally corresponds to the "crash pulse" of the vehicle in which it is installed. For example, a vehicle having relatively "stiff" frame may have a crash pulse of approximately 30 milliseconds. In other words, a period of 30 milliseconds will elapse between the time in which a collision occurs at the front end of the vehicle and the time in which the force of such a collision is transmitted back to the vehicle occupant and the cushion is fully inflated.

In contrast, a vehicle having a relatively "soft" frame may have a crash pulse of approximately 50 milliseconds or more. Thus, an air bag installed in an exemplary vehicle having a relatively "stiff" frame may be required to inflate 20 milliseconds or more faster than an air bag installed in an exemplary vehicle have a relatively "soft" frame. To effect this faster inflation, a larger and more powerful source of inflation gas will typically be required.

Air bags have generally been divided into two types, i.e. driver side and passenger side. Driver side air bags have often been fitted into the vehicle steering column. These air bags, which typically have a circular configuration when fully inflated, have tended to be smaller because of the relatively small space between the driver and the steering wheel.

Passenger side air bags, on the other hand, have generally been fitted into the vehicle dash ahead of the front seat passenger. Due to the relatively large space between the front seat passenger and the dash, these air bags have tended to be larger than driver side air bags. When fully inflated, a passenger side air bag will generally have a box-like configuration.

Due to various considerations, driver side air bags and passenger side air bags have often been constructed of different materials. Specifically, driver side air bags have frequently been constructed of a base fabric of either nylon or polyester which has been coated with chloroprene (neoprene), silicone or other appropriate elastomeric resin to reduce permeability. Passenger side air bags have generally been constructed of uncoated fabric.

It is important to design an air bag such that a specific rate of deflation is achieved. In other words, the air bag should quickly deflate in a controlled manner as it is impacted by the vehicle occupant. Adequate support will thereby be provided to the vehicle occupant without excessive rebounding.

To achieve the desired rate of the deflation, driver side air bags have generally been constructed having relatively large vent holes through which the inflation gas is expelled. It should be appreciated that an air bag intended to be used in a vehicle having a stiff frame will generally be required to deflate faster than an air bag for use in a soft frame vehicle. Thus, the specific size of these vent holes will generally be related to the crash pulse of the vehicle.

Because the inflation gas is generally very hot, the vent holes have typically been defined in the rear panel of the air bag opposite the front panel which is impacted by the driver. While face burns are largely avoided by placing the vent holes in this location, finger and hand burns have often occurred. Additionally, relatively large vent holes often allow sodium azide particulate in the inflation gas to escape into the vehicle's passenger compartment.

Due to these problems, the air bag industry has developed various alternative designs which do not have large vent holes. One such design is referred to as a "hybrid" air bag. The hybrid air bag is a driver side air bag utilizing a coated front panel which is generally impermeable to air, while having a back panel constructed of an uncoated fabric. This uncoated fabric, like the uncoated fabric utilized to produce many passenger side air bags, provides a degree of air permeability by venting air through the fabric's natural interstices.

Prior art uncoated fabrics utilized in vehicle air bags rely heavily on processing parameters to control air permeability. For example, different air permeability values have often been achieved by adjusting such factors as yarn preparation, weaving, scouring or heat setting. A problem with attempting to achieve a specific air permeability in this manner is that such processing parameters are often difficult to control on a consistent basis. As a result, relatively large variations in air permeability are often seen between respective lots of uncoated fabric which have ostensibly been prepared to the same permeability specification. In fact, variations of +/−three (3) cubic feet per minute (CFM) at ½ inch of water pressure are not uncommon. These wide variations in permeability may undesirably result in large variations in the deflation rates of respective air bags produced for a particular vehicle model.

SUMMARY OF THE INVENTION

The present invention recognizes and addresses the foregoing disadvantages, and others of prior art constructions and methods.

Accordingly, it is an object of the present invention to provide an improved air bag for use in a motor vehicle.

It is a more particular object of the present invention to provide an improved vehicle air bag which is constructed substantially entirely of an uncoated fabric.

It is a further object of the present invention to provide an improved vehicle air bag constructed substantially of an uncoated fabric which has multiple panels of various permeabilities.

It is also an object of the present invention to provide an improved fabric material for use in an air bag.

It is a further object of the present invention to provide an improved fabric material for use in an air bag which has a substantially consistent permeability across the fabric web.

It is an additional object of the present invention to provide improved methods of producing a vehicle air bag.

Some of these objects are achieved by a vehicle air bag for use with an on-board inflator mechanism. When constructed as a driver side air bag, it may include a front panel of substantially uncoated fabric having a permeability of less than approximately two (2) CFM. A back panel of uncoated fabric is also provided having a permeability of greater than approximately two (2) CFM. In presently preferred embodiments, the back panel will have a permeability falling within a range of approximately four (4) CFM to six (6) CFM. (Unless otherwise indicated, permeability values given herein are expressed with reference to a pressure drop of ½ inch of water.) With the exception of a hole define therein for providing fluid communication with the on-board inflator mechanism, the back panel is substantially continuous throughout its extent.

The air bag may also be constructed as a passenger side air bag further having a body panel and a pair of side panels. In this case, the body panel will preferably have a permeability of less than approximately two (2) CFM, whereas the side panels will preferably each have a permeability of greater than approximately five (5) CFM. Preferably, the permeability of the side panels will fall within a range of approximately five (5) CFM to seven (7) CFM.

Controlled permeability in the various panels may be achieved according to the invention by a multiplicity of needle punctures having a larger diameter at a first side of the fabric than at a second side of the fabric. In this case, the fabric of the front or body panels may be arranged such that the first side defines a portion of an exterior of the air bag. Conversely, the fabric of the back and side panels may be arranged such that the first side defines a portion of an interior of the air bag.

Some objects of the present invention are also achieved by a method of producing a vehicle air bag constructed substantially entirely of an uncoated fabric. Preferably, a first step in such a method is to provide an uncoated fabric of appropriate synthetic yarn. A first portion of the uncoated fabric may then be selectively processed to achieve a first preselected permeability. Next, a second portion of the uncoated fabric may also be selectively processed to achieve a second preselected permeability which is higher than the first preselected permeability. The vehicle air bag may then be constructed utilizing the first portion and second portion of the uncoated fabric for various panels thereof.

In a presently preferred methodology, the first and second portions of the uncoated fabric are selectively processed by being calendered under selected temperature and pressure conditions to achieve a low reference permeability. The portions are then further processed to increase a porosity thereof such that a selected permeability is achieved on a consistent basis. In the case of a front panel of a driver side air or a body panel of passenger side air bag, this controlled permeability would generally be less than two (2) CFM. For a back panel of a driver side air bag this controlled permeability would generally be greater than approximately two (2) CFM, whereas a controlled permeability of greater than five (5) CFM would generally be selected for side panels of a passenger side air bag.

This further processing may be accomplished by moving the uncoated fabric at a selected speed past a plurality of needles reciprocating at a selected rate into and out of engagement therewith. In this case, a plurality of barbless needles are preferably utilized if the preselected permeability is less than a threshold permeability. If the preselected permeability is greater than the threshold permeability, a plurality of barbed needles are preferably utilized for this purpose. The threshold permeability may generally fall within a range of 3.0 CFM to 4.0 CFM, with a value of approximately 3.5 CFM being typical.

Alternatively, the uncoated fabric may be moved past a plurality of fluid jets, preferably water jets, which impact the uncoated fabric under selected operating conditions. Pores created by the fluid jets may be set in the uncoated fabric by heat. As a result, the fabric will maintain the desired permeability level during use. This desired permeability may be less than or greater than that of the fabric prior to processing.

Fluid jet processing may also be utilized to provide an air bag having a predetermined thread count. In this case, the woven fabric may have a preselected starting thread count in which at least a warp thread count thereof is less than that of the final thread count. Often, the warp thread count will be at least approximately eight (8) percent less than the final warp count, with a starting warp thread count greater than fifteen (15) percent less not being unusual. In a method to achieve the final thread count, the plurality of fluid jets are directed onto the woven fabric until the final thread count is achieved. After the final thread count is achieved, the plurality of fluid jets may be further directed onto the woven fabric to also achieve a desired final permeability.

Particularly in the case of nylon, the woven fabric after fluid jet treatment may tend to have a lower permeability along its center portion than at the side portions thereof. The present invention, however, produces a uniform permeability across the fabric web by selectively varying fluid passage through the fabric. In presently preferred embodiments, this is accomplished utilizing an improved substrate which is situated contiguous to the fabric during fluid jet processing. The substrate includes a multiplicity of aperture rows oriented in the transverse direction. The apertures of each such row will have a greater diameter at the center than at the periphery thereof.

Other objects, features and aspects of the present invention are discussed in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying drawings, in which:

FIG. **1** is a back elevation of a typical prior art driver side air bag;

FIG. **2** is a side elevation of a driver side air bag constructed in accordance with the present invention;

FIG. **3** is a perspective view of a passenger side air bag constructed in accordance with the present invention;

FIG. **4** diagrammatically illustrates calendering of an uncoated fabric to selectively reduce the permeability thereof;

FIG. **5** diagrammatically illustrates needling of a calendered uncoated fabric to selectively increase the porosity thereof;

FIG. **6**A and **6**B respectively illustrate a barbless needle and a barbed needle such as may be used in the needling apparatus of FIG. **5**;

FIG. **7** diagrammatically illustrates a cross section of a calendered uncoated fabric which has been needled to show the configuration of the respective punctures;

FIG. **8** diagrammatically illustrates a water jet apparatus which may alternatively be used to vary the porosity of the uncoated fabric;

FIG. 9 is an enlarged diagrammatic representation of a fabric being processed with an apparatus such as that shown in FIG. 8;

FIG. 10 is a diagrammatic representation of the fabric of FIG. 9 as processed to have an increased permeability;

FIG. 11A and 11B are photomicrographs at ten (10) times magnification of an exemplary woven fabric before and after fluid jet processing according to the present invention;

FIGS. 12A and 12B are photomicrographs at sixty-five (65) times magnification of the fabric shown in FIGS. 11A and 11B before and after fluid jet processing according to the present invention;

FIG. 13 is a diagrammatic representation of the fabric of FIG. 9 as processed to have a reduced permeability;

FIG. 14 is a diagrammatic representation illustrating variations in permeability across a fabric web which may result from fluid jet processing; and

FIG. 15 illustrates a modified forming screen which may be utilized to produce a fabric web having a generally uniform permeability thereacross.

Repeat use of reference characters in the present specification and drawings is intended to represent same or analogous features or elements of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention, which broader aspects are embodied in the exemplary constructions.

Referring now to

FIG. 1, a typical driver side air bag of the prior art is indicated generally at **10**. Air bag **10** includes a front panel (not shown) which is attached to a back panel **12** via stitching or other appropriate means of such attachment. Back panel **12** defines an inflator hole **14** to provide fluid communication with a source of inflation gas. As discussed above, the front panel and back panel **12** are each typically constructed of fabric which has been coated with an elastomeric resin to be practically impermeable to the passage of air. Accordingly, vent holes, such as vent holes **16** and **18**, are defined in back panel **12** to expel the inflation gas so that air bag **10** will quickly deflate as desired.

As described above, the use of vent holes has often produced a number of undesirable consequences, such as finger or hand burns and excessive gas particulate. Additionally, air bags constructed of coated material tend to be more bulky than air bags constructed of uncoated material. Coated material is also generally more expensive to produce than uncoated material. As used herein, it is to understood that the term "coated" refers to the coating of a fabric with some type of elastomer or the like to reduce its air permeability. Thus, the term "uncoated" is not intended preclude coating of the fabric with some other type of material having a relatively small weight in comparison with the base fabric for purposes other than reducing air permeability.

FIG. 2 illustrates a driver side air bag **20** of the present invention which is constructed substantially entirely of uncoated fabric. Air bag **20** has a back panel **22** and a front panel **24** attached about their respective circumferences by stitching or other appropriate means of such attachment. Back panel **22** defines therein an inflator hole **26**, but preferably is otherwise continuous throughout its extent. In other words, back panel **22** may be generally devoid of large vent holes, such as vent holes **16** and **18** of air bag **10**.

Instead of relying upon the natural interstices of the fabric as produced only by weaving to provide inflation gas venting, the uncoated fabric of back panel **22** and front panel **24** has been processed according to the invention to provide a controlled permeability. As indicated by the relative occurrence of stippling in FIG. **2**, back panel **22** will preferably have a greater permeability than front panel **24**. In presently preferred embodiments, the permeability of back panel **22** is greater than approximately two (2) CFM, often falling within a range of approximately four (4) CFM to six (6) CFM. In an exemplary construction, the permeability of back panel **24** may fall within a range of five (5) CFM to six (6) CFM. Front panel **24** will generally have a permeability of less than two (2) CFM.

FIG. 3 illustrates a passenger side air bag **28** of the present invention. Air bag **28** is also constructed substantially entirely of uncoated fabric, which has not been uncommon in passenger side air bags of the prior art. Air bag **28** differs from the prior art, however, in that respective panels thereof are produced according to the invention to have a controlled permeability. As a result, greater consistency in deflation may be achieved.

A body panel **30** forms a top, front and bottom portion of air bag **28**. Preferably, body panel **30** has a permeability of less than two (2) CFM. A left side panel **32** and a similar right side panel (not shown) are stitched or otherwise attached to body panel **30**. The controlled permeability of such side panels is preferably greater than five (5) CFM, and may generally fall within a range of approximately five (5) CFM to seven (7) CFM. Air bag **28** further includes a snout assembly **34** to provide fluid communication with the source of inflation gas.

Presently preferred methods by which controlled permeability may be achieved in the fabric utilized in air bags **20** and **28** may be best understood with reference to FIGS. **4** through **8**. According to at least one exemplary technique, an important step in providing this controlled permeability is to stabilize the permeability of the fabric at a low reference permeability. Once this low reference permeability is achieved, further processing may be utilized to selectively increase fabric porosity. The amount and character of such further processing will then determine the final permeability of the fabric.

The low reference permeability is preferably achieved by calendering, as illustrated in FIG. **4**. In this regard, a supply roll **38** provides uncoated fabric **40** of the type which is appropriate for use in an air bag. A number of specifications for air bag fabric are well known, including weight, thickness and strength.

Such yarn may have a size of 600 denier or other yarn size appropriate for the exigencies of a particular application. Preferably, the fabric of supply roll **38** will be either woven or warp knitted fabric constructed substantially entirely of synthetic fibers. Because nylon is somewhat hygroscopic, i.e. water absorbing, some presently preferred embodiments may frequently utilize polyester yarn. In fact, polyester is particularly preferred if the fabric is to be calendered.

Referring again to FIG. **4**, fabric **40** is delivered from supply roll **38** into a calender device **42**, which includes a relatively large center roller **44** and a pair of smaller rollers **46** and **48**. As shown, fabric **40** extends between rollers **44** and **46** and then around roller **48**. After leaving calender device **42**, fabric **40** is delivered to take up roll **50** as illustrated.

Rollers **46** and **48** apply heat and pressure onto contiguous portions of center roller **44**. As a result, fabric **40** is calendered on one side at two nip locations **52** and **54**. It has been found that calendering fabric **40** at a temperature of 300 degrees Fahrenheit and a pressure of 3000 lbs. per square inch produces a reference permeability of less than one (1) CFM, as is generally desired according to presently preferred methodology.

After the reference permeability is achieved, further processing is utilized to raise the overall permeability of the fabric to a desired level. FIG. **5** illustrates one presently preferred method which may be utilized for this purpose. As shown, fabric **40** is moving in the direction of arrow A under the influence of an appropriate conveyor mechanism **56**. A needle carrier **58** having thereon a plurality of needles (referenced generally as **60**) is shown reciprocating into and out of engagement with fabric **40**, as indicated by arrow B. Preferably, needles **60**, which may generally have a size of 18 gauge to 40 gauge, will engage the calendered side of fabric **40**.

The density of needles **60** (in number of needles per unit area), along with the speed of fabric **40** and the rate of reciprocation of carrier **58** (as measured in strokes per minute (SPM)) gives a characteristic number of punctures per square inch (PPSI). It has been found that, for a particular needle size operating under defined conditions, a PPSI value may be selected to achieve a desired permeability with greater consistency than has generally been achieved by relying only upon processing parameters as has been the case in the past. In fact, it has been found that a particular air permeability may be achieved according to the invention with a variation of less than approximately +/−1.0 CFM, as opposed to the +/−3.0 CFM as was common in the prior art.

When relatively low levels of permeability are desired, needles **60** are preferably barbless needles, such as needle **60**A of FIG. **6**A. As shown, needle **60**A includes a conical tip portion **62** integrally extending into a tapered shaft portion **64**. Because of the shape of tapered shaft portion **64**, greater permeability may often be produced at a given PPSI level by increasing the depth of needle penetration.

With barbless needles, it has been found that upon achieving a certain threshold permeability, further needling becomes largely ineffective to provide additional increases in permeability. Generally, this threshold permeability will fall within a range of 3.0 CFM to 4.0 CFM, with a value of approximately 3.5 CFM being typical.

If it is desired that the permeability of fabric **40** be greater than this threshold permeability, a barbed needle, such as needle **60**B of FIG. **6**B, may be utilized. Like needle **60**A, needle **60**B includes a generally conical tip portion **66** integrally extending into a tapered shaft portion **68**. However, needle **60**B further includes at least one barbed portion **70** which functions to enlarge the size of the puncture created when fabric **40** is engaged. It should be appreciated that, while a barbed needle could be utilized to produce permeabilities below the threshold permeability, such is often not desired. This is because the use of a barbed needle creates a rougher fabric surface, which may not be desirable in panels (such as front panel **24** of air bag **20** and body panel **30** of air bag **28**) which may come into contact with the face of a vehicle occupant.

FIG. **7** diagrammatically illustrates a plurality of punctures **72** which may be produced in fabric **40** by needling as described. As shown, the conical configuration of needles **60** produces punctures **72** which have a greater diameter at a first side **74** of fabric **40** than at a second side **76** of fabric **40**. This generally produces a more laminar flow as gas moves through punctures **72** from side **74** to side **76** than vice versa. As a result, the permeability of fabric **40** is generally greater when side **74** is situated on an interior of the air bag. Thus, to provide a lower permeability in front of the occupant's face, front panel **24** of air bag **20** and body panel **30** of air bag **28** are configured having first side **74** on the exterior. Further smoothness is provided to the occupant's face by the fact that side **74** is also preferably the side which has been calendered. Other areas of air bags **20** and **28** are preferably constructed having first side **74** on the interior to enhance permeability.

An alternative methodology of producing a controlled permeability in fabric **40** is illustrated in FIG. **8**. In this case, fabric **40** is shown moving beneath a plurality of fluid jet headers **78** under the influence of an appropriate conveyor mechanism **80**. Each of headers **78** emits a plurality of fluid jets, which strike fabric **40** with predetermined operating characteristics. As a result, pores are created to allow the fluid to flow therethrough.

Several factors will affect the permeability of fabric **40** produced in a fluid jet system, such as that illustrated. In addition to total fluid energy delivered, such factors include the number of orifices in each of headers **78**, as well as the spacing and size of these orifices. Generally, conveyor **80** will include a wire mesh substrate which fabric **40** will have a tendency to mimic as it is impacted by the fluid jets. Thus, the type of substrate will also affect the permeability, as well as whether the fluid jet system is flat as illustrated or a rotary type system.

In order to permit lower jet energies to form the pores, fabric **40** is preferably uncalendered when fluid jet processing is utilized. Elimination of calendering in this case facilitates the use of nylon fabric in addition to polyester fabric as described above. In fact, nylon may be preferred in some applications because of its thermal resistance properties.

Preferably, the fluid jets emitted by header **78** are water jets. This water is shown being collected in respective collection basins **82**, from which it is carried away. It can be seen that the system of FIG. **8** is similar to a "hydroentanglement" system of the type utilized to produce nonwoven materials. Some of the principals of a hydroentanglement apparatus are described in U.S. Pat. No. 3,494,821, issued Feb. 10, 1972 to Evans, which is incorporated herein by reference.

Generally, nonwoven material produced in a hydrogentanglement apparatus is subjected to a relatively strong vacuum to remove absorbed water. However, when used with a woven fabric, such as fabric **40**, a vacuum treatment of this type will generally tend to make fabric **40** have a relatively stiff "hand." Thus, a strong vacuum is preferably not utilized to dry fabric **40**, although a weaker vacuum may be utilized to remove excess water. Final drying may be achieved using a tenter oven **84** which allows fabric **40** to retain a relatively "soft" hand.

Oven drying in this manner may also serve to heat set the pores formed by the fluid jets. As a result, such pores will remain in fabric **40** to give the desired air permeability level. To facilitate heat setting, it is desirable that, once dry, fabric **40** remain heated to a temperature of approximately 350 degrees Fahrenheit to 380 degrees Fahrenheit for a period exceeding approximately 20 to 30 seconds.

It will be appreciated that fluid jets **78** selectively move and shape the individual yarns of fabric **40** to produce the desired permeability. In addition to achieving increased permeability, this technique may also be used to produce lower permeability fabrics.

As will be explained, processing by fluid jets will largely eliminate anomalies produced in the fabric web during weaving. Such anomalies have contributed to relatively large variations in permeability which have occurred in unprocessed fabric on a lot-to-lot basis. The filaments of unprocessed yarns have tended to be somewhat loose, causing yarn flattening when subjected to air flow pressure. Because the configuration produced by fluid jet processing is predictable, consistent permeability may be achieved on a controlled basis.

Referring now to FIG. **9**, a portion **86** of woven fabric suitable for use in an air bag is illustrated. This exemplary fabric is constructed as a plain weave, having fill yarns **88** interwoven with warp yarns **90**. While a plain weave is illustrated for purposes of explanation, it should be appreciated that other suitable weave configurations may also be utilized.

FIG. **10** diagrammatically illustrates portion **86** as it may appear after processing to produce a higher permeability. This configuration may be achieved utilizing a plurality of fluid jets **92** which are directed generally into the fabric interstices. As can be seen, fluid forced through the interstices in this manner has caused the cross-sectional configuration of warp yarns to become more "square." This square configuration causes the respective interstices to more closely approximate a well-defined passage for transmission of fluid. Thus, the permeability of the fabric has been increased.

It will also be appreciated that the square configuration of warp yarns **90** and natural fabric contraction causes fill yarns **88** to become more "crimped" as they extend over and under adjacent of warp yarns **88**. This crimping effect may be heat set into the fabric as described above to retain the "square" configuration of the warp yarns. As a result, the defined configuration of the interstices will be maintained.

FIGS. **11A** and **11B** are photomicrographs at ten (10) times magnification showing an exemplary fabric before and after fluid jet processing to produce a controlled permeability. FIGS. **12A** and **12B** are similar photomicrographs at sixty-five (65) times magnification of the same fabric. The particular fabric shown is constructed of 630 denier multifilament nylon yarn.

It can be seen in the photomicrographs that the filament bundles of each yarn exhibit a shape prior to processing which is relatively undefined. This lack of definition results in migration of individual filaments into the interstitial regions. Where such has occurred, passage of fluid therethrough will be inhibited. Additionally, weaving anomalies result in significant variations in the size and configuration of respective interstices across the fabric web.

After processing, however, it can be seen that the interstices are characterized by a generally regular and well-defined appearance. This has resulted from a reshaping of the yarn fiber, as can easily be seen in FIGS. **11B** and **12B**. Thus, a relatively controlled permeability may be achieved.

Referring again to FIG. **10**, it can be seen that warp yarns **90** are closer together than before processing as in FIG. **9**. Thus, a final air bag fabric may be produced in this manner to have a higher warp thread count than that of the unprocessed fabric. Often, some increase in the thread count of the fill yarns may also be achieved. Generally, the unprocessed fabric will have a warp thread count which is at least eight (8) percent greater than that of the unprocessed fabric. In fact, increases of greater than fifteen (15) percent may often be achieved.

As a result, a fabric having a selected thread count may be produced from woven fabrics having a lower thread count. Other methods for achieving a higher thread count fabric, such as overfeeding, often lead to a reduction in permeability. In this case, however, high thread count fabrics may be achieved while concurrently achieving higher permeabilities. To illustrate results which may be achieved with fluid jet processing, consider the following examples:

EXAMPLE I

As an example, consider a prior art air bag fabric constructed of a 630 d multifilament nylon yarn. A typical thread count for such a fabric in its finished state may be 41×41, with a final permeability falling within a range of 1–2 CFM. The following are the approximate thread counts of the fabric at various processing stages:

1. Weaving at 38.5×41
2. Scouring produces 42×41
3. Heat setting at 41×41

Thus, a woven fabric having a thread count of 38.5.×41 may produce an air bag fabric having a thread count of 41×41.

As described above, fluid jet processing causes an increase in the warp thread count. Thus, fluid jet processing of the above fabric may produce the following thread counts at various processing stages:

1. Weaving at 38.5×41
2. Scouring produces 42×41
3. Fluid jet processing at 46×42
4. Heat setting at 46×42

It can be seen that the final thread count of the fabric will be considerably higher if fluid jet processing is employed than would have been otherwise expected. Such a higher thread count may be desirable in many cases because of the enhanced strength and mass which may thereby be provided to the fabric.

In other cases, it may be desirable to produce a fabric having a 41×41 thread count as in the prior art case. The following indicates the thread counts which may be expected at various processing stages in this situation:

1. Weaving at 35×41
2. Scouring produces 38×41
3. Fluid jet processing produces 41×41
4. Heat setting at 41×41

Thus, a fabric having a desired thread count, e.g., 41×41, may be produced from a woven fabric having a lower thread count, e.g., 35×41 versus 38.5×41, when fluid jet processing is utilized.

Additionally, the fabric processed according to the invention may be reconstructed to exhibit a desired permeability, such as falling within a range of four (4) to ten (10) CFM for this exemplary case. This is in contrast to the prior art in which a 41×41 construction would have generally produced a permeability falling in the range of 1–2 CFM.

EXAMPLE II

Side impact air bags are now being installed into a limited number of vehicle models. According to industry estimates, the various models which will be equipped with side impact air bags is expected to increase. Because of the short crash pulse in a side impact, these air bags utilize a relatively powerful source of inflation gas.

To provide strength and thermal resistance in light of the powerful inflator utilized in a side impact bag, a relatively "beefy" bag construction is preferably employed. For example, a suitable fabric for this purpose may be constructed of an 840 d multifilament yarn having a thread count as high as practicable. Current practice in the industry has produced such fabric generally having a thread count of no greater than about 35×35. According to the present invention, however, it is believed that fluid jet processing may produce such a fabric having a thread count of at least 38×38.

As noted above, fluid jet processing may also be utilized to achieve a lower permeability in the fabric. Thus, referring now to FIG. **13**, portion **86** is diagrammatically shown after processing to produce such a lower permeability. This may be accomplished utilizing fluid jets **94** generally directed to the cross-over points of the fabric yarns. Preferably, the fluid pressures in this case will be significantly lower than the pressures utilized to produce higher permeability fabrics. Such lower pressures cause the fiber bundles to "blossom," thereby becoming somewhat flattened as shown. The smaller interstices thus produced may then be heat set to consistently yield a desired lower permeability.

Particularly in the case of nylon fabric, processing with water jets can, in some cases, cause some contraction toward the center. Thus, while a known permeability may be produced on a lot-to-lot basis, the permeability of a particular lot may vary slightly across the fabric's web surface. In this regard, FIG. **14** illustrates a typical fabric web **96** having warp yarns running in the warp direction ("W") and fill yarns running in the fill, or transverse, direction ("F").

It will now be assumed that fabric web **96** has been processed with equivalent processing parameters in its fill direction. In this case, contraction of the fabric may cause a lower permeability (LP) portion **98** to be produced along the longitudinal center region of web **96**. Fabric web **96** will thus exhibit greater permeability (GP) portions **100** and **102** extending along its lateral side regions.

To compensate for this effect where it occurs, the present invention selectively varies fluid flow through fabric web **96** across the transverse direction. Specifically, more fluid is allowed to flow through L.P. portion **98**, while less fluid is directed through G.P. portions **100** and **102**. As a result, the yarns will be redistributed across the web in a more uniform manner. Accordingly, the permeability across the fabric web will also be substantially uniform.

One technique for achieving this uniform permeability provides a modified substrate of the type for use in an apparatus as that shown in FIG. **8**. Referring to FIG. **15**, substrate **104** is illustrated comprising a generally planar element **106**. As shown, a multiplicity of substantially linear rows of apertures are defined in element **106** for passage of fluid from the fluid jets. Preferably, each row of apertures linearly extends in the transverse direction of element **106**, as shown.

Individual apertures of each row are configured into regions of varying diameter which complement the greater permeability and lesser permeability regions of fabric web **96**. Specifically, planer element **106** may be constructed having greater diameter ("GD") apertures in center portion **108**, with lesser diameter ("LD") apertures in side portions **110** and **112**.

While not necessary in many cases, it may be desirable to configure the apertures to have a successively increasing diameter toward the center, such as shown in the enlargement at **114**. In such embodiments, apertures on either side of one or more large center apertures **116** will decrease successively. Apertures having the smallest diameter will thus be located at the end of the respective row.

It can thus be seen that the invention provides an improved technology for constructing an air bag substantially entirely of uncoated material while achieving a more consistent permeability than was generally achievable with the prior art. While presently preferred embodiments of the invention and presently preferred methods of practicing the same have been shown and described, it should be understood that various modifications and variations may be made thereto by those of ordinary skill in the art. For example, instead of utilizing a modified substrate, similar results may be achieved by varying the operating characteristics of fluid jets in the transverse direction. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only and it is not intended to be limitative of the spirit and scope of the invention so further set forth in the following claims.

What is claimed is:

1. A method of producing an air bag fabric having a predetermined final permeability and a predetermined final thread count, said method comprising the steps of:

(a) providing a woven fabric constructed substantially entirely of synthetic yarn, said woven fabric having a preselected starting thread count in which at least a warp thread count thereof is less than that of said final thread count;

(b) directing a plurality of fluid jets onto the woven fabric under selected operating conditions such that the final permeability and the final thread count are achieved; and

(c) selectively heating the fabric to set the final permeability and the final thread count.

2. A method as set forth in claim **1**, wherein the warp thread count of said preselected starting thread count is at least approximately eight (8) percent less than a warp thread count of said final thread count.

3. A method as set forth in claim **1**, wherein step (b) comprises the steps of:

(d) directing the plurality of fluid jets onto the woven fabric to achieve the final thread count; and

(e) after the preselected final thread count is achieved, continuing to direct the plurality of fluid jets onto the woven fabric to achieve the final permeability.

4. A method as set forth in claim **1**, wherein the plurality of fluid jets comprises a plurality of water jets.

5. A method as set forth in claim **4**, wherein step (c) comprises heating the fabric at a temperature of 350 degrees Fahrenheit for a duration of at least twenty (20) seconds.

6. A method as set forth in claim **1**, wherein the plurality of fluid jets are oriented in a transverse direction to said woven fabric and wherein passage of fluid through the fabric is selectively varied across said transverse direction such that a substantially uniform permeability is achieved thereacross.

7. A method of producing an air bag fabric having a predetermined permeability, said method comprising the steps of:

(a) providing a woven fabric constructed substantially entirely of synthetic yarn;

(b) providing a plurality of fluid jets oriented in a transverse direction to said woven fabric;

(c) directing said plurality of fluid jets onto the woven fabric under selected operating conditions; and

(d) selectively varying passage of said fluid through said fabric in said transverse direction thereby achieving said predetermined permeability with substantial uniformity across said fabric.

8. A method as set forth in claim 7, further comprising the step of selectively heating the fabric to set the predetermined permeability.

9. A method as set forth in claim 7, wherein said synthetic yarn is nylon.

10. A method as set forth in claim 7, wherein said synthetic yarn is polyester.

11. A substrate surface for use in an apparatus utilizing a plurality of fluid jets to process a fabric web such that a generally uniform permeability is achieved thereacross, said substrate surface comprising:

a generally planar element extending in a longitudinal direction and having first and second opposite lateral sides, said planar element defining a multiplicity of substantially linear rows of apertures for passage of fluid from the fluid jets, each said row of apertures extending from a first end located adjacent one of said opposite lateral sides in a transverse direction of said planar element to a second end adjacent another of said opposite lateral sides;

apertures of an individual row located toward said first and second ends generally having a diameter less than apertures located toward a center of said individual row, wherein placement of said fabric web interposing said planar element and a plurality of fluid jets will cause more fluid to flow through a center region of said web to achieve the generally uniform permeability.

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